P516759.PDF [Page: 3 of 40]

DEFENCE R&D DÉFENSE

Multistatic Sonar Non-Acoustical Data Analysis Tools

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Lever Computational Services
3045 Olivet Street, #38
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Contract #W7707-9-7206/001/HAL

The scientific or technical validity of this Contract Report is entirely the responsibility of the contractor and the contents do not necessarily have the approval or endorsement of Defence R & D Canada

Defence R&D Canada

Contractor Report

DREA CR 2000-045

September 2001

National Defence Défense nationale

Canada

P516759.PDF [Page: 4 of 40]

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Defence Research Establishment Atlantic

Contractor Report

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September 2001

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Abstract

DREA sea trials require the planning of vessel and sensor locations and movements before an experiment, and the collection of the realized data as it occurs at sea. This non-acoustical data is vital in understanding the measured acoustical results, and is collected by the NADAS shipboard system. A series of computer programs have been developed over the years by a variety of authors in order to analyze this non-acoustical data after the experiments. The demands on the software have increased due to user requests and the improved positional accuracy available at sea. This report covers the version of this software that incorporates these changes.

The modifications to the software included a general cleaning up of the code and converting it to run on the Linux operating system. The major enhancements include the use of the World Geodetic System-84 rather than a simple spheroid to represent the earth. The computations of relative ranges, relative and geographic bearings, bistatic aspect, and bistatic angles given source, receiver and target information have been implemented. Additionally, further quality assurance testing of the data has been added and the ability to use the software for trial planning purposes.

This report will describe the software suite, the algorithms used, and the typical usage of the programs.

Résumé

Les essais en mer du CRDA exigent la planification des emplacements et mouvements des navires et capteurs avant le début d'une expérience ainsi que la collecte des données obtenues en mer. Ces données non acoustiques sont essentielles à la compréhension des résultats acoustiques mesurés, et elles sont recueillies par le système embarqué NADAS. Avec les années, différents auteurs ont mis au point une série de programmes informatiques pour analyser les données non acoustiques après les expériences. Les exigences imposées au logiciel ont augmenté en raison des demandes des utilisateurs et de la meilleure précision de position disponible en mer. Ce rapport a trait à la version du logiciel incorporant ces modifications.

Les modifications du logiciel comprennent un nettoyage général du code et sa conversion au système d'exploitation Linux. Les principales améliorations incluent le recours au Système géodésique mondial 84 plutôt qu'à une simple sphéroïde représentant la Terre. On a également incorporé le calcul des distances relatives, des relèvements relatifs et géographiques, de l'aspect bistatique et des angles bistatiques à partir d'information sur la source, le récepteur et la cible. Par ailleurs, il est maintenant possible d'effectuer d'autres essais d'assurance de la qualité des données et d'utiliser le logiciel pour la planification des essais.

Ce rapport décrira la suite logicielle, les algorithmes utilisés et l'application typique des programmes.

P516759.PDF [Page: 7 of 40]

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Executive summary

Background: The Defence Research Establishment Atlantic (DREA) Naval Sonar Section conducts trials or experiments at sea involving acoustic sources and sensors. The sources and sensors may be located on a vessel movable under its own power, i.e. a ship, or a buoy which may be fixed in position or move with the ocean currents. The main objective of these experiments is to measure the acoustic performance of the sensors. In order to analyze the acoustic results, the absolute and relative positions, depths, and a variety of other data for each source and receiver must be recorded along with the acoustic results. This is done by a shipboard data collection system known as the Non-Acoustical Data Acquisition System (NADAS).

The NADAS produces a computer file containing all the events of an experiment. Some events such as a latitude and longitude from a Global Positioning System (GPS) fix are recorded every few seconds or minutes. Other events are recorded whenever they occur. All of this data must be checked for reasonableness and accuracy before it can be used in the analysis of the acoustic results.

The process of checking and then analyzing this data for several vessels that may be used in a single experiment requires computer programs. Over the past twenty or so years a collection of computer programs has been developed in-house at DREA by a variety of people. In 1994 a contract was let to organize and assess and document this collection [4]. In the five years since the programs have fallen out of use and a new program has been used which incorporated some needed improvements such as some multistatic calculation and smoothing.

Objectives: The intent of this project is to update the collection of programs as documented in 1994 [*] to incorporate the changes made in the newer program as well as a few other changes and improvements to the system. These changes include the use of the World Geodetic System-84 rather than a simple spheroid to represent the earth; the computations of relative ranges, relative and geographic bearings, bistatic aspect, and bistatic angles given source, receiver and target information; and further quality assurance testing of the data.

The updated software is to run on the operating system Linux rather than the VAX computer using VMS and the GNU compiler where it currently resides.

The final objective is to add new programs that can be used to plan vessel location and movements for future experiments.

Work Performed: The first task of the project was to gather all of the existing software and documentation. This proved more difficult than expected as several versions were available and they did not match the existing documentation from [4]. Once the code was collected the programs had to be studied. The internal documentation in the program code itself was usually good but a few key routines had almost no helpful comments. Particularly lacking was any documentation of the mathematical methods used by the programs.

Having sorted out the code some changes were made to eliminate any obvious errors.

P516759.PDF [Page: 9 of 40]

Specifications were created for a data error checking program and specifications for the new calculations and incorporation of the WGS-84 were laid out.

The code was moved to a Linux based system, and made to work there. At this point test data and a few files of real data were processed.

This report was prepared to provide full documentation of the updated system.

Summary of Results: The desired new computations are now implemented, and the WGS-84 is used in all calculations. The programs run on a Linux system, and this version can now be considered the main correct copy superceding all the previous packages.

Report Contents: The rest of this report documents the older versions of the programs and the mathematical methods used as well as the newest version. A User's Guide for the current version is also included.

Leverman, Brian, 2000 Multistatic Sonar Non-Acoustical Data Analysis Tools
DREA CR 2000-045 Defence Research Establishment Atlantic

P516759.PDF [Page: 10 of 40]

Sommaire

Contexte. La Section du sonar naval du Centre de recherches pour la défense Atlantique (CRDA) effectue des essais ou des expériences en mer à l'aide de sources et de capteurs acoustiques. Les sources et capteurs peuvent se trouver à bord d'une embarcation se déplaçant par sa propre énergie, soit un navire, ou être montés sur une bouée fixe ou se déplaçant avec les courants océaniques. L'objectif principal de ces expériences consiste à mesurer les performances acoustiques des capteurs. Afin d'analyser les résultats acoustiques, il est nécessaire d'enregistrer les positions absolues et relatives, les profondeurs et diverses autres données pour chaque source et récepteur, avec les résultats acoustiques. Ces enregistrements s'effectuent à l'aide d'un système de collecte de données à bord du navice appelé système d'acquisition de données non acoustiques (NADAS).

Le NADAS produit un fichier informatique contenant tous les éléments d'une expérience. Certains éléments, comme la latitude et la longitude fournies par le système de positionnement mondial (SPM), sont enregistrés à des intervalles de quelques secondes ou minutes. D'autres éléments sont enregistrés au moment où ils se produisent. Il est essentiel de vérifier la vraisemblance et l'exactitude de toutes ces données avant de les utiliser pour l'analyse des résultats acoustiques.

Des programmes informatiques sont nécessaires pour vérifier et analyser les données de plusieurs navires dans le cadre d'une expérience particulière. Durant les quelque vingt dernières années, diverses personnes à l'intérieur du CRDA ont développé un ensemble de programmes informatiques. En 1994, un contrat a été octroyer dans le but d'organiser, d'évaluer et de documenter ces programmes [4]. Dans les cinq années qui ont suivi, ces programmes ont cessé d'être utilisés et un nouveau programme incorporant certaines des améliorations nécessaires, comme les calculs multistatiques et le lissage, a été mis en application.

Objectifs. Ce projet vise à mettre à jour l'ensemble des programmes documentés en 1994 [*] afin d'incorporer les modifications contenues dans le programme plus récent, ainsi que d'autres modifications et améliorations apportées au système. Ces modifications incluent le recours au Système géodésique mondial 84 plutôt qu'à une simple sphéroïde représentant la Terre, le calcul des distances relatives, des relèvements relatifs et géographiques, de l'aspect bistatique et des angles bistatiques à partir d'information sur la source, le récepteur et la cible, ainsi que d'autres essais d'assurance de la qualité des données.

Le logiciel à jour doit tourner sous le système d'exploitation Linux plutôt que sur l'ordinateur VAX utilisant VMS et le compilateur GNU, où il réside actuellement.

L'objectif final consiste à ajouter de nouveaux programmes pouvant servir à planifier les emplacements et mouvements des navires en vue d'expériences futures.

Travaux effectués. La première tâche du projet consistait à recueillir l'ensemble du logiciel et de la documentation existants. Cela s'est avéré plus difficile que prévu, car plusieurs versions étaient disponibles et ne correspondaient pas à la documentation existante de [4]. Une fois le code recueilli, il a fallu étudier les programmes. La documentation interne du code des programmes comme tel était habituellement satisfaisante, mais quelques routines clés ne comportaient presque aucun commentaire utile.

P516759.PDF [Page: 11 of 40]

Il manquait tout particulièrement la documentation des méthodes mathématiques qu'utilisent les programmes.

Après le tri du code, on a apporté certaines modifications dans le but d'éliminer les erreurs évidentes. Des spécifications ont été établies relativement à un programme de contrôle des données erronées, à de nouveaux calculs et à l'incorporation du WGS-84.

Le code a été transféré et adapté à un système fonctionnant sous Linux. Des données d'essai et quelques fichiers de données réelles y ont alors été traités.

Ce rapport a été préparé dans le but de fournir de la documentation complète sur le système à jour.

Résumé des résultats. Les nouveaux calculs désirés sont maintenant en application, et le WGS-84 est utilisé dans tous les calculs. Les programmes sont exécutés dans un système Linux, et la version actuelle peut maintenant être considérée comme la principale copie correcte remplaçant tous les logiciels précédents.

Contenu du rapport. Le reste de ce rapport documente les anciennes versions des programmes et les méthodes mathématiques utilisées, ainsi que la version la plus récente. Un guide d'utilisation de la version courante est également inclus.

Leverman, Brian, 2000 Multistatic Sonar Non-Acoustical Data Analysis Tools
DREA CR 2000-045 Defence Research Establishment Atlantic

P516750.PDF [Page: 12 of 40]

Table of contents

Abstract i

Executive summary iii

Sommaire v

Table of contents vii

Acknowledgements viii

1.0 Overall Description of the Data and Processing 9

2.0 The Previous Versions 12

2.1 Description 12

2.2 Mathematical Methods 15

3.0 The Current Version 16

3.1 Description 16

3.2 Mathematical Methods 16

3.3 List of Programs and Their Functions 16

3.4 Using the Programs 19

4. Conclusions 20

5. Appendices 21

6. References 32

P516759.PDF [Page: 13 of 40]

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The computer code has existed at DREA for many years in many versions with many people contributing new code, corrections, and utilities. My thanks to all of them for their past efforts.

The algorithms for calculating range and bearing form two latitude, longitude points were obtained from Professor Richard B. Langley of the University of New Brunswick, and also from the National Geodetic Survey of the National Oceanic and Atmospheric Administration.

1. Overall Description of the Data and Processing

The non-acoustical data collected by the NADAS system can only be recorded on board ships. Any positional information concerning sources or receivers not attached to a ship must be made from a vessel, for example a range and bearing from radar, or known from other sources outside of the NADAS system. This data and software system is outlined in [1].

Let us consider the information in one file generated on one vessel by the NADAS system, remembering that several vessels may be involved in a single experiment. The data is collected as a series of data lines (as detailed in [3] and included as Appendix A) of the following general format:

<data_id>,<date>,<time>,[<data_item>,[<data_item>,…]]<CR><LF>

where:

<data_id>,	is a number identifying the type of data line
<date>,	is the date in format yyyy/mm/dd
<time>,	is the time in the format hh:mm:ss
<data_item>	is a data item(s) as defined for each <data_id>
<CR><LF>	are the carriage return, line feed ASCII control characters

The data lines are supposed to be in chronological order, so we can picture the data from this one vessel as a table or spread sheet with the date and time defining each line and one or more pieces of data entered in one of the columns as defined by the 91 different data_ids (not all 91 data_ids are currently in use – some gaps are present in the numbering system). This structure can be pictured as shown below, using just a few data_ids and lines of data to illustrate:

Date/time	Data_id 11 LORAN-C	Data_id 13 GPS	Data_id 17 Waypoint	Data_id 41 Ship name	Data_id 91 Radar
1st	-	-	-	name	-
2nd	lat/long	-	-	-	-
3rd	-	-	-	-	Range Bearing Contact #
4th	-	lat/long	-	-	-
5th	lat/long	-	-	-	-
6th	-	-	lat/long heading	-	-

			distance		
7th	-	lat/long	-	-	-
8th	lat/long	-	-	-	-
etc...	-	-	-	-	-

The first thing to notice is that a variety of methods are used to record the ship's position. The various techniques can each be trusted in various circumstances. The first thing a user would like to do is make sure that the data in such a table was self-consistent. This would involve making sure that the date/time information is ascending as expected. Then each column could be checked to see that each data value was within a reasonable range.
Next the change in position from one line to the next, if any, should be checked against the time elapsed to make sure the speed is reasonable. Finally the results from each of the different positional measurement techniques should be compared to each other to insure that they are in reasonable agreement. You will notice that the positional information is not necessarily available for each method at the same times so interpolation would have to be used to make the comparison. Any discrepancies would have to be investigated from other sources, such as a ship's log, and the NADAS file edited using a text editor. Much of the checking can be done by examination of plots produced by the checking software using the SAPLOT system [2]

Once satisfied that the data for each individual vessel was correct, the user must look at the relationships from one vessel to the next. The first consideration is that both NADAS files cover the same experiment, meaning that the dates and times should overlap. The vessels should not be in the same place at the same time. Measurements of range or bearing to an acoustic source or receiver taken from each vessel should be consistent with each other with respect to the two ships positions.

The older versions of the software converted the files from the raw NADAS format to a modified format called the NAD format. All of the programs except the first in the processing cycle, which did the NADAS to NAD conversion, were written to expect the NAD format.

Having successfully completed this data verification the user can then proceed with the analysis. The main problem now is that the times in one file will probably not exactly correspond to the times in another file. This requires that the data in one of the files be interpolated so that each file will consist of a series of lines with the same times. This is necessary as most of the calculations comparing the range, bearing, etc., are done at a series of identical times.

P516759.PDF [Page: 16 of 40]

Now the user can proceed with the calculations. The sorts of values typically calculated with the data from two or more vessels are:

- range and bearing (true)
- range and bearing (relative)
- calculated latitude and longitude
- calculated latitude and longitude error
- calculated ship velocity
- calculated relative speed between two objects
- calculated relative bearing between two objects

These results and others are the data needed for the analysis of the acoustical results of the experiment, which is of course the main reason for the sea trials.

The process of doing the calculations usually involves preparing two files of NADAS data from two different vessels. These files will only contain the data of one data_id type. One or both of these files can be interpolated to make the dates and times match exactly. The analysis can them be performed.

2. The Previous Versions

2.1 Description

The programs available at the start of this project came from two sources.

The first was the older collection of programs which is somewhat documented in [4]. This code has dates in the inline comments as early as 1980. Most of this code seems to have been created in the very late 1980s period. Several copies of some of the programs exist, and there did not seem to be one 'standard' version available. The programs did not seem to match exactly with the available documentation. There was no documentation of the mathematical methods used

The package was primarily composed of a number of separate programs, which the user could run in a sequence of their own choosing to achieve the results they desired. The programs and other associated files are listed below.

Main Programs to do desired user calculations:

NAD_SUBTRACT_LAT_LONG
NAD_STRIP
NAD_MAKE_TRB
NAD_CALC_SPEED_BEARING
NAD_CALC_RANGE_BEARING
NAD_CALC_RANGE_BEARING_2
NAD_CALC_LAT_LONG
NAD_ADD_LAT_LONG
FILE_TO_NAD
NAD_EXTRAP_POSIT

Main programs to do interpolations:

NAD_STD_TIME_INTERVAL
NAD_INTERPOL_AND_INCLUDE
NAD_INTERPOL_AND_EXCLUDE
NAD_LABEL_POINT

Programs to do file processing:

NAD_MERGE_TEMP

NAD_SPLIT

Main Programs to do plotting:

NAD_LAB
NAD_LAB2
NAD_PLOT
NAD_NAV_PLOT

Subroutines used by programs to do interpolations:

NAD_NUM_TYPE
INTER_AVG
INTERPOLATE
INTER_VECTOR

Subroutines used by NAD_SPLIT:

HEADER
NAVGAT
UCLOSE
DAYTIM
DECPOS

Subroutines used by plotting programs:

T_RISE
LABEL
EOFILE

Miscellaneous subroutines and programs:

VECTOR
NAD_TO_METRIC
ANG
DEGRAD
NAD_TEST_LABEL

General utility subroutines and functions:

COORD
DECODE
DEC_JUL_DAY
DEC_JUL_HR
FORMATIT
GET_STRING
INPUTI
INPUTR
INPUT_FILENAME
INTER_RAT
JULIAN
LAST_WORD
LEN1
LEN2
LEFT_1
NAD_DATA_LABEL
NAD_DATA_LINE
NAD_DATA_TYPE
NAD_N_COLUMN
NAD_N_DATA
SELEC
SELECH
SELEK
SPHERE
UN_DEC_JUL_DAY
UN_DEC_JUL_HR
UN_JULIAN
VALIDELIM

Text files used by the code:

NAD_DATA_TYPE.TXT
NAD_DATA_LINE.TXT
NAD_DATA_LABEL.TXT
NAD_DATA_COLUMN.TXT
FORMAT.TXT
NAD_INTERP_DATA_LABEL.TXT
NAD_N_DATA.TXT

The second was a newer single program developed by J. Theriault, which incorporated much of the functionality of the first package, and added some new desired calculations.
This program used the following files:

Main programs:

EVSORT

Subroutine Libraries:

INPUT
OUTPUT
OPEN_FILE_HP

Utility files:

MAKEFILE
TEST_SCRIPT

Text files used by the code:

TRACKS_INCLUDE

2.2 Mathematical Methods

The code for the earlier versions all use straight linear interpolations when interpolating data between two points, whether the data is latitude or longitude or angles or bearings etc. The calculations of distances between a pair of latitude and longitude points is done using an iterative method that uses a simple Lambert spheroid as a model of the earth's surface.

3. The Current Version

3.1 Description

Several major changes in the overall function were made in arriving at the new version. The primary one was to abandon the NAD format altogether and carry the NADAS format throughout the processing cycle. All of the file names and program names have been changed to reflect this difference and to prevent confusion with the older package. Several new programs have been added to the package to perform the new functionality of the enhanced package. The files involved are now named as described below.

3.2 Mathematical Methods

The current version now does all interpolations taking into account the curvature of the earth's surface using the WGS-84 model [5] of the earth's surface. Calculations of ranges and bearings also use the WGS-84 model for increased accuracy.

The algorithms used for the calculations were adopted from software obtained from Professor Richard B. Langley of the University of New Brunswick, and also from the National Geodetic Survey of the National Oceanic and Atmospheric Administration (see www.ngs.noaa.gov/PC_PROD/pc_prod.shtml). These algorithms are both based on the Modified Rainsford's Method with Helmert's elliptical terms, built on the algorithms of T. Vincenty. These algorithms are considered standard in the geodetic community. The calculations needed and the thinking behind them is explained at www.census.gov/geo/www/faq-index.html. This site holds the Frequently Asked Questions (FAQ) page for GIS and Geodesy.

3.3 List of Programs and their Functions

Main Programs to do desired user calculations:

NADAS_SUBTRACT_LAT_LONG
NADAS_STRIP
NADAS_MAKE_TRB
NADAS_CALC_SPEED_BEARING
NADAS_CALC_RANGE_BEARING
NADAS_CALC_RANGE_BEARING_2
NADAS_CALC_LAT_LONG
NADAS_ADD_LAT_LONG
FILE_TO_NADAS
NADAS_EXTRAP_POSIT

Main programs to do interpolations:

NADAS_STD_TIME_INTERVAL
NADAS_INTERPOL_AND_INCLUDE
NADAS_INTERPOL_AND_EXCLUDE
NADAS_LABEL_POINT

Programs to do file processing:

NADAS_MERGE_TEMP
NADAS_SPLIT

Main Programs to do plotting:

NADAS_LAB
NADAS_LAB2
NADAS_PLOT
NADAS_NAV_PLOT

Subroutines used by programs to do interpolations:

NADAS_NUM_TYPE
NADAS_INTER_AVG
NADAS_INTERPOLATE
NADAS_INTER_VECTOR

Subroutines used by NADAS_SPLIT:

NADAS_HEADER
NADAS_NAVGAT
NADAS_UCLOSE
NADAS_DAYTIM
NADAS_DECPOS

P516759.PDF [Page: 23 of 40]

Subroutines used by plotting programs:

NADAS_T_RISE
NADAS_LABEL
NADAS_EOFILE

Miscellaneous subroutines and programs:

NADAS_VECTOR
NADAS_TO_METRIC
NADAS_ANG
NADAS_DEGRAD
NADAS_TEST_LABEL

General utility subroutines and functions:

NADAS_COORD
NADAS_DECODE
NADAS_DEC_JUL_DAY
NADAS_DEC_JUL_HR
NADAS_FORMATIT
NADAS_GET_STRING
NADAS_INPUTI
NADAS_INPUTR
NADAS_INPUT_FILENAME
NADAS_INTER_RAT
NADAS_JULIAN
NADAS_LAST_WORD
NADAS_LEN1
NADAS_LEN2
NADAS_LEFT_1
NADAS_NAD_DATA_LABEL
NADAS_NAD_DATA_LINE
NADAS_DATA_TYPE
NADAS_N_COLUMN
NADAS_N_DATA
NADAS_SELEC
NADAS_SELECH
NADAS_SELEK
NADAS_SPHERE
NADAS_UN_DEC_JUL_DAY
NADAS_UN_DEC_JUL_HR

P516759.PDF [Page: 24 of 40]

NADAS_UN_JULIAN
NADAS_VALIDELIM

Text files used by the code:

NADAS_DATA_TYPE.TXT
NADAS_DATA_LINE.TXT
NADAS_DATA_LABEL.TXT
NADAS_DATA_COLUMN.TXT
NADAS_FORMAT.TXT
NADAS_INTERP_DATA_LABEL.TXT
NADAS_N_DATA.TXT

3.4 Using the Programs

The executable programs and the necessary shell scripts are located on a Linux based operating system in the Naval Sonar Section. The executables are located in the usual \bin directory under the name NADAS. The source code and all text and documentation files are located in the usual \source directory.

The usual method of using the programs would be to create a new empty subdirectory in the users \home directory and place the raw NADAS files there. This should allow the user to have a different subdirectory for the files associated with each experiment, and to keep the files and whatever output files generated in an organized structure. The necessary executables should be readily available by placing the \bin\nadas directory name in the user's account search path.

The user could then proceed through the sequence of the data editing steps, the extraction and interpolation steps, and finally the analysis steps.

P516759.PDF [Page: 25 of 40]

4. Conclusions

The version of the software described in this report should now provide all of the functionality available in all the other previous versions. New functionality has been added to fulfill the demands of the users. Data checking and error detection during processing have been improved. Using the WGS-84 model of the earth has provided increased accuracy.

This package will provide those who wish to work with NADAS data a more complete and reliable set of software tools.

5. Appendices

Appendix A NADAS Output File Standard

The following text is contained in a computer file NADASEROUT.TXT [3] and is considered the current description of the output recorded from the NADAS shipboard data collection system.

```
NADASEROUT.TXT          Tue Jul  4 13:10:04 1989

This file describes the NADAS serial output format.


1. Serial RS-232 Configuration:

     o baud rate = 9600
     o 8 bits/character
     o 1 stop bit
     o no parity


2. Data Line Format:

     <data number>,<daytime>,<data> <carriage-return> <line-feed>

 data number is described in section 3 below.
 daytime is the date and time in the format of data number type 1.
 daytime is the time at which the data on the same line were
 measured.

3. Description of Current Data Numbers, and Recommended Output
Intervals

Interval #  Description
-------------------------------------------------------------------
10s       1  Present daytime in UCT (GMT or Zulu)
10s       2  Local time offset
10s       3  Present Julian day
          4
          5
          6
          7
          8
          9
20s      10  Dead-reckoning position
20s      11  LORAN-C position
fix      12  Transit satellite position
20s      13  GPS/Navstar position
60s      14  Omega position
```

P516759.PDF [Page: 27 of 40]

20s	15	DECCA-nav position
event	16	Event mark position
	17	Waypoint position
	18	
	19	
10s	20	Water depth at ship location
60s	21	Wave height at ship location
	22	
	23	
	24	
	25	
	26	
	27	
	28	
	29	
10s	30	Ship velocity (doppler log speed and gyro heading)
60s	31	Wind speed relative to ship
60s	32	Wind direction relative to ship
60s	33	True wind velocity (speed and direction)
5s	34	Ship propellor revolutions/minute
	35	
	36	
	37	
	38	
	39	
60s	40	Cruise number
60s	41	Ship
60s	42	Chief scientist
60s	43	NADAS cruise ID comments
immed	44	Comment from NADAS operator
	45	
	46	
	47	
	48	
	49	
60s	50	Surface water temperature at ship location
immed	51	XBT information
immed	52	XSV information
immed	53	XCTP information
immed	54	XSCP information
60s	55	Air temperature at ship location
	56	
	57	
	58	
	59	
	60	Raw voltmeter data
	61	
	62	
	63	
	64	
	65	
	66	
	67	
	68	

P516759.PDF [Page: 28 of 40]

```
          69
60s*      70  Quiet status of ship
60s*      71  Engine status of ship
          72
          73
          74
          75
          76
          77
          78
          79
          80  AN/ARR-75 receiver status
          81
          82
          83
          84
          85
          86
          87
          88
          89
          90 Radar range, bearing (relative), contact #
          91 Radar range, bearing (true), contact #
          92
          93
          94
          95
          96
          97
          98
          99
```

* also immediately on any change of status

4. Specification of Current Data Numbers:

```
     1  Present daytime in UCT (GMT or Zulu)

001,1999/12/31,23:59:59
 #  year mo dy hr mn s
```

Note that this is meant for synchronizing other computers. The time given is the time that this time line is sent. Unlike the other data types, no data follows the time.

* I recommend that this time be sent no more often than every 10s and no less often than every 60s.

P516759.PDF [Page: 29 of 40]

```
     2  Local time offset

003,1999/12/31,23:59:59,-23.99
 #  year mo dy hr mn s  hours

 * I recommend that this time be sent no more often than every 10s
and no less often than every 60s.

-------------------------------------------------------------------
     3  Present Julian day

004,1999/12/31,23:59:59,365
 #  year mo dy hr mn s  day

 * I recommend that this day be sent no more often than every 10s and
no less often than every 60s.

-------------------------------------------------------------------
    10  Dead-reckoning position

010,1999/12/31,23:59:59,89:59.99N,179:59.99W,9999
 #  year mo dy hr mn s  deg min   deg  min   err
      lat       lon

 err = 0000 for no error

-------------------------------------------------------------------
    11  LORAN-C position

011,1999/12/31,23:59:59,89:59.99N,179:59.99W,9999
 #  year mo dy hr mn s  deg min   deg  min   err

 err = 0000 for no error

-------------------------------------------------------------------
    12  Transit satellite position

012,1999/12/31,23:59:59,89:59.99N,179:59.99W,99999999
 #  year mo dy hr mn s  deg min   deg  min  errs sat el it
      lat       lon

 err1 = 0: doppler count and # iterations good
 err1 = 1: doppler count no good
 err1 = 2: # iterations no good
 err1 = 3: doppler count and # iterations both no good
 err2 = 0: max elevation angle and doppler deviation good
 err2 = 3: max elevation angle no good
 err2 = 4: doppler deviation no good
 err2 = 7: max elevation angle and doppler deviation no good
 sat = satellite number
 el = maximum satellite elevation (degrees)
 it = number of iterations

-------------------------------------------------------------------
```

P516759.PDF [Page: 30 of 40]

```
    13  GPS/Navstar position

013,1999/12/31,23:59:59,89:59.99N,179:59.99W
 #  year mo dy hr mn s  deg min   deg  min
      lat       lon

-------------------------------------------------------------------------
    14  Omega position

014,1999/12/31,23:59:59,89:59.99N,179:59.99W,99
 #  year mo dy hr mn s  deg min   deg  min   err
      lat       lon

 err = 00 for no error

-------------------------------------------------------------------------
    15  DECCA-nav position

015,1999/12/31,23:59:59,89:59.99N,179:59.99W
 #  year mo dy hr mn s  deg min   deg  min
      lat       lon

-------------------------------------------------------------------------
    16  Event mark position

016,1999/12/31,23:59:59,89:59.99N,179:59.99W,Z
 #  year mo dy hr mn s  deg min   deg  min
      lat       lon

 Z is event mark symbol

-------------------------------------------------------------------------
    17  Waypoint position

017,1999/12/31,23:59:59,89:59.99N,179:59.99W,359.9,99999.9,359.9,9999
9.9,34,Z
 #  year mo dy hr mn s  deg min   deg  min   bear  range   bear
range
      lat       lon        rhumb       great circle

 34 is Furuno waypoint method: 31 = DR,  32 = Omega,  34 = Loran-C
 Z is waypoint label character

-------------------------------------------------------------------------
    20  Water depth at ship location

020,1999/12/31,23:59:59,9999.9
 #  year mo dy hr mn s  depth

 depth is in metres


-------------------------------------------------------------------------
```

P516759.PDF [Page: 31 of 40]

```
    21  Wave height at ship location

021,1999/12/31,23:59:59,99.9
 #  year mo dy hr mn s  height

 height is in metres

-------------------------------------------------------------------------
    30  Ship velocity (doppler log speed and gyro heading)

030,1999/12/31,23:59:59,99.9,359.9
 #  year mo dy hr mn s  spd  dirn

 speed is in knots, direction is in degrees relative to true North

-------------------------------------------------------------------------
    31  Wind speed relative to ship

031,1999/12/31,23:59:59,999.9
 #  year mo dy hr mn s  spd

 speed is in knots, direction is in degrees relative to ship's head

-------------------------------------------------------------------------
    32  Wind direction relative to ship

032,1999/12/31,23:59:59,359.9
 #  year mo dy hr mn s  dirn

 speed is in knots, direction is in degrees relative to ship's head

-------------------------------------------------------------------------
    33  True wind velocity (speed and direction)

033,1999/12/31,23:59:59,999.9,359.9
 #  year mo dy hr mn s  spd   dirn

 speed is in knots, direction is in degrees relative to true North

-------------------------------------------------------------------------
    34  Ship propellor revolutions/minute

034,1999/12/31,23:59:59,999,999
 #  year mo dy hr mn s port stbd

-------------------------------------------------------------------------
    40  Cruise number

040,1999/12/31,23:59:59,Q2345678901234567890
 #  year mo dy hr mn s  Cnumber

 Cruise number may be any single-line ASCII string identifying the
cruise
```

```
------------------------------------------------------------------------
    41  Ship

041,1999/12/31,23:59:59,Quest678901234567890
 #  year mo dy hr mn s  ship

 Ship may be any single-line ASCII string identifying the ship

------------------------------------------------------------------------
    42  Chief scientist
042,1999/12/31,23:59:59,scientist012324567890
 #  year mo dy hr mn s

 Scientist may be any single-line ASCII string identifying the Chief
scientist

------------------------------------------------------------------------
    43  NADAS cruise ID comments
043,1999/12/31,23:59:59,IDcomments...up to 80 characters
 #  year mo dy hr mn s

 IDcomments... may be any single-line ASCII string identifying the
cruise

------------------------------------------------------------------------
    44  Comment from NADAS operator
044,1999/12/31,23:59:59,comment...up to 80 characters
 #  year mo dy hr mn s

 comment... may be any single-line ASCII string comment

------------------------------------------------------------------------
    50  Surface water temperature at ship location

050,1999/12/31,23:59:59,-99.9
 #  year mo dy hr mn s  temp

 temperature is in C

------------------------------------------------------------------------
    51  XBT information

------------------------------------------------------------------------
    52  XSV information

------------------------------------------------------------------------
    53  XCTP information

------------------------------------------------------------------------
    54  XSCP information


------------------------------------------------------------------------
```

P516759.PDF [Page: 33 of 40]

```
    55  Air temperature at ship location

055,1999/12/31,23:59:59,-99.9
 #  year mo dy hr mn s  temp

 temperature is in C

--------------------------------------------------------------------------
    60  Raw voltmeter data

--------------------------------------------------------------------------
    70  Quiet status of ship

--------------------------------------------------------------------------
    71  Engine status of ship

--------------------------------------------------------------------------
    80  AN/ARR-75 receiver status

--------------------------------------------------------------------------
    90  Radar data range (nm), bearing (relative), contact #

090,1999/12/31,23:59:59,99999.9,359.9,99
 #  year mo dy hr mn s  range   bear  contact
--------------------------------------------------------------------------
    91  Radar data range (nm), bearing (true), contact #

091,1999/12/31,23:59:59,99999.9,359.9,99
 #  year mo dy hr mn s  range   bear  contact
```

5. Background Information

- o one line of data takes about 40 ms to send
- o about 25 lines of data can be sent every second
- o for a 1% duty cycle, a line of data is sent every 4 seconds
- o 10 knots = 5.144 m/s
- o 6 second time interval @10 knots for navigational accuracy of 30m

Appendix B NAD File Standard

The following text is contained in a computer file NADASEROUT.TXT and is considered the current description of the output recorded from the NADAS shipboard data collection system.

```
In this document,the format of the NAD file type is specified.  The file is
dived into two parts: the header and the data.  The starts after the word
CURVE; the header is everything before the word curve.  The current
valid entries in the header are as follows:
CRUISE
SHIP
SCIENTIST
STATION
COMMENT
COMMENT_OP

Anything can follow the words CRUISE and SHIP, as long as the cruise and
ship names are the last words on the line.  All lines can be deleted;  extra
comment lines can be added.  After the word curve, nothing but the data is
permitted.  All data lines must be in the following format:

<data id number> <date> <time> <data1> <data2>. . <carriage-return> <line-
feed>

The data id numbers are defined below.  The date must be in the form YY MM
DD;
the time must be in decimal hours; the data entries are in the units
specified
below with the data id numbers.


1  Present daytime in UCT (GMT or Zulu)
2  Local time offset
3  Present Julian day
4
5
6
7
8
9
10  Dead-reckoning position
11  LORAN-C position
12  Transit satellite position
13  GPS/Navstar position
14  Omega position
15  DECCA-nav position
16  Event mark position
17  Waypoint position
18
19
20  Water depth at ship location
21  Wave height at ship location
```

P516759.PDF [Page: 35 of 40]

```
22
23
24
25
26
27
28
29
30  Ship velocity (doppler log speed and gyro heading)
31  Wind speed relative to ship
32  Wind direction relative to ship
33  True wind velocity (speed and direction)
34  Ship propellor revolutions/minute
35
36
37
38
39
40  Cruise number
41  Ship
42  Chief scientist
43  NADAS cruise ID comments
44  Comment from NADAS operator
45
46
47
48
49
50  Surface water temperature at ship location
51  XBT information
52  XSV information
53  XCTP information
54  XSCP information
55  Air temperature at ship location
56
57
58
59
60  Raw voltmeter data
61
62
63
64
65
66
67
68
69
70  Quiet status of ship
71  Engine status of ship
72
73
74
75
76
77
```

P516759.PDF [Page: 36 of 40]

```
 78
 79
 80  AN/ARR-75 receiver status
 81
 82
 83
 84
 85
 86
 87
 88
 89
 90 Radar range, bearing (relative), contact #
 91 Radar range, bearing (true), contact #
 92
 93
 94
 95
 96
 97
 98
 99
100 Calculated Range (km) and bearing (true) data
110 Calculated Latitude and Longitude data
111 Calculated Lat/Long Error
120 Calculated Ship Velocity (from Lat/Long)
130 Aircraft Latitude, Longitude, Altitude, Speed, Heading
```

P516759.PDF [Page: 37 of 40]

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DREA sea trials require the planning of vessel and sensor locations and movements before and experiment, and the collection of the realized data as it occurs at sea. This non-acoustical data is vital in understanding the measured acoustical results, and is collected by the NADAS shipboard system. A series of computer programs suites has been developed over the years by a variety of authors in order to analyze this non-acoustical data after the experiments. The demands on the software have increased due to user requests and the improved positional accuracy available at sea. This report covers the version of this software that incorporates these changes.

The modifications to the software included a general cleaning up of the code and converting it to run on the Linux operating system. The major enhancements include the use of the World Geodetic System-84 rather than a simple spheroid to represent the earth. The computations of relative ranges, relative and geographic bearings, bistatic aspect, and bistatic angles given source, receiver and target information have been implemented. Additionally, further quality assurance testing of the data has been added and the ability to use the software for trial planning purposes

This report will describe the software suite, the algorithms used, and the typical usage of the programs.

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Software
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P516759.PDF [Page: 40 of 40]

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